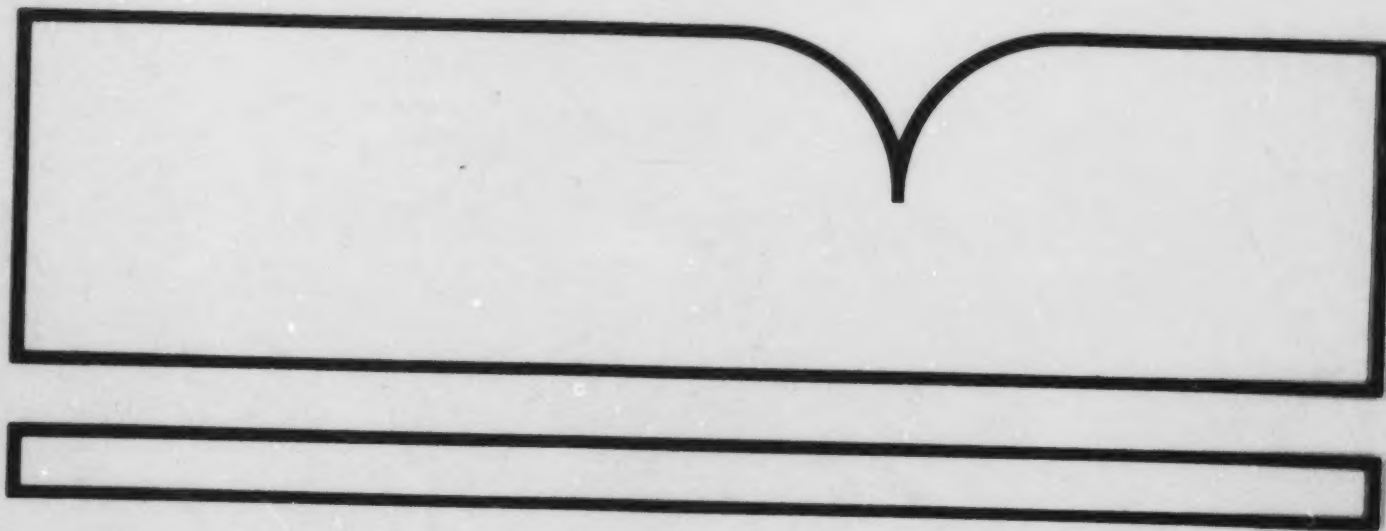


PB84-170174

Benzene Emissions from Maleic Anhydride Plants
Background Information for Proposal to
Withdraw Proposed Standards

(U.S.) Environmental Protection Agency
Research Triangle Park, NC

Mar 84



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Benzene Emissions From Maleic Anhydride Plants — Background Information for Proposal to Withdraw Proposed Standards

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16. ABSTRACT This document contains information that formed the basis for the decision to withdraw standards proposed for the maleic anhydride industry April 18, 1980 (45 FR 26660). The report includes a summary of industry changes since proposal, a summary of public comments relevant to the withdrawal decision, and the rationale for the decision to withdraw proposed standards.			
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Benzene Emissions from Maleic Anhydride Plants — Background Information for Proposal to Withdraw Proposed Standards

Emission Standards and Engineering Division

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

March 1984

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ENVIRONMENTAL PROTECTION AGENCY

Background Information
for Benzene Emissions from Maleic
Anhydride Manufacture

Prepared by:

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3/1/84

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(Date)

1. The Federal Register notice proposes withdrawal of proposed national emission standards (45 FR 26660; April 18, 1980) for benzene emissions from existing and new maleic anhydride plants.
2. Copies of this document have been sent to the following Federal Departments: Labor, Health and Human Services, Defense, Transportation, Agriculture, Commerce, Interior, and Energy; the National Science Foundation; the Council on Environmental Quality; State and Territorial Air Pollution Program Administrators; EPA Regional Administrators; Local Air Pollution Control Officials; Office of Management and Budget; and other interested parties.
3. The comment period for review of this document is 30 days from date of proposal in the Federal Register. Mr. Gilbert H. Wood may be contacted at (919) 541-5578 regarding the date of the comment period.
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1. SUMMARY

On April 18, 1980, the U.S. Environmental Protection Agency (EPA) proposed a national emission standard for hazardous air pollutants (NESHAP) (45 FR 26660) that would regulate benzene emissions from maleic anhydride plants under the authority of Section 112 of the Clean Air Act as amended. Public comments were requested on the proposal in the Federal Register publication. Thirty-five comment letters were received and twenty-three oral presentations were made at the public hearing. Comments submitted relevant to the withdrawal decision, along with responses to these comments, are summarized in this document. The summary of comments and responses serves as the basis for the proposal to withdraw the proposed standards.

1.1 SUMMARY OF INDUSTRY CHANGES SINCE PROPOSAL

Since the standards for benzene emissions from maleic anhydride plants were proposed (April 18, 1980; 45 FR 26660), benzene emissions from this source category have declined considerably. This reduction is due to plant closures, feedstock switches, and installation of controls. These changes are described in more detail in Section 2.2.1 of this document. Table 1-1 compares the nationwide baseline benzene emission and health impacts due to maleic anhydride process vents at proposal with current estimated impacts.

TABLE 1-1. CHANGES IN INDUSTRY IMPACTS

Impact	At proposal	Current
Benzene emissions (Mg/yr)	5,800	960
Leukemia incidence (cases/yr)	0.46	0.029
Maximum lifetime risk	2.3×10^{-4}	7.6×10^{-5}

1.2 SUMMARY OF PROPOSAL TO WITHDRAW PROPOSED STANDARDS

The Administrator is proposing to withdraw proposal of the benzene standards for maleic anhydride plants. This decision is based on several factors, including the broad amount of control currently within the source category, the relatively small amount of emissions, the trend away from using benzene as a feedstock, the small estimated leukemia incidence and maximum lifetime risk at current levels, and the small reduction in these health risks achievable with add-on controls. This decision is discussed in greater detail in Section 2.2.1.

2. SUMMARY OF PUBLIC COMMENTS

Commenters, affiliations, and EPA docket number assigned each comment are shown in Table 2-1. Thirty-five letters and documents on the proposed standard and its background information document (BID) were received. Because the proposed standards are being proposed for withdrawal, only comments and responses relevant to that decision are addressed in this document. Significant comments have been divided into the following 2 categories:

1. Selection of Maleic Anhydride Process Vents for Regulation
2. Health and Environmental Impacts

2.1 SELECTION OF MALEIC ANHYDRIDE PROCESS VENTS FOR REGULATION

2.1.1 Selection of Source Category

Comment: According to one commenter, the Administrator has recognized that risk from pollutant sources may be insignificant even if the pollutant is an airborne carcinogen listed under Section 112. According to the Administrator, "This may occur, for example, because . . . sources have installed adequate controls on their own initiative or in response to other regulatory requirements." The commenter believes the maleic anhydride industry has installed such controls and cited the operating status of the following plants as examples (Part II Docket Item IV-D-22).

The Reichhold (New Jersey) maleic anhydride plant has closed and will be dismantled (p. 61-62 of IV-D-22).

Koppers does not intend to reopen its Bridgeville, Pennsylvania, maleic anhydride plant unless very substantial changes in the economics of the industry occurred. If the plant reopened, it would operate (as in the past) with emission controls sufficient to meet the standard (Attachment E

TABLE 2-1. LIST OF COMMENTERS ON THE PROPOSED NATIONAL
EMISSION STANDARD FOR BENZENE EMISSIONS FROM MALEIC
ANHYDRIDE PLANTS

Commenter	Docket No.	Affiliation
J. T. Barr	IV-D-1, Part I IV-D-5, Part II	Air Products and Chemicals, Inc. Box 538 Allentown, Pennsylvania 18105
E. A. Treanor	IV-D-2, Part I	American Petroleum Institute (API) 2101 L Street, Northwest Washington, D.C. 20037
D. B. Rathbun	IV-D-3, Part I	API
C. H. Fishman	IV-D-4, Part I	Wilmer & Pickering 1666 K Street, N.W. Washington, D.C. 20006
N. J. King	IV-D-5, Part I	Wilmer & Pickering
F. S. Lisella	IV-D-6, Part I IV-D-19, Part II	Center for Disease Control Department of Health and Human Services U.S. Public Health Service Atlanta, Georgia 30333
J. J. Moon	IV-D-7, Part I IV-D-21, Part II	Phillips Petroleum Company Bartlesville, Oklahoma 74004
P. F. Infante	IV-D-8, Part I	Occupational Safety and Health Administration (OSHA) U.S. Department of Labor Washington, D.C. 20210
Chemical Manufacturer's Association (CMA)	IV-D-9, Part I IV-D-22, Part II IV-F-8, Part II	Chemical Manufacturers Association (CMA) 1825 Connecticut Avenue, N.W. Washington, D.C. 20009
J. M. DeMeester	IV-D-10, Part I	Dow Chemical Company Bennett Building 2030 Dow Center Midland, Michigan 48640

(Continued)

TABLE 2-1. LIST OF COMMENTERS ON THE PROPOSED NATIONAL
EMISSION STANDARD FOR BENZENE EMISSIONS FROM MALEIC
ANHYDRIDE PLANTS (Continued)

Commenter	Docket No.	Affiliation
R. K. Meyers	IV-D-11, Part I	Texaco, Inc. P.O. Box 509 Beacon, New York 12508
R. C. Sterrett	IV-D-12, Part I	Ashland Chemical Company P.O. Box 2219 Columbus, Ohio 43216
API	IV-D-13, Part I IV-F-9, Part II	API
G. C. Iannelli	IV-D-14, Part I	General Council of the United States Department of Commerce U.S. Department of Commerce Washington, D.C. 20230
F. M. Brower	IV-D-2, Part II	Dow Chemical Company
L. Behr	IV-D-4, Part II	Private Citizen 64 Maple Lane Greens Farms, Connecticut 06346
A. F. Montgomery	IV-D-6, Part II	National Science Foundation (NSF) Washington, D.C. 20550
M. L. Joseph	IV-D-7, Part II IV-D-20, Part II	OSHA
D. Rector	IV-D-8, Part II	State of Michigan Department of Natural Resources Box 30028 Lansing, Michigan 48909
H. H. Hovey, Jr.	IV-D-9, Part II	New York State Department of Environmental Conservation 50 Wolf Road Albany, New York 12233
J. Ruspi	IV-D-10, Part II	The Aerospace Corporation 20030 Century Boulevard Germantown, Maryland 20767
D. J. Goodwin	IV-D-11, Part II	Illinois Environmental Protection Agency 2200 Churchill Road Springfield, Illinois 62706

TABLE 2-1. LIST OF COMMENTERS ON THE PROPOSED NATIONAL
EMISSION STANDARD FOR BENZENE EMISSIONS FROM MALEIC
ANHYDRIDE PLANTS (Continued)

Commenter	Docket No.	Affiliation
L. D. Johnson	IV-D-14, Part II	Rohm and Haas Company Environmental Control Department Box 584 Bristol, Pennsylvania 19007
R. M. Gifford	IV-D-15, Part II	Pfizer Chemicals Division 235 East 42nd Street New York, New York 10017
M. Lennon	IV-D-16, Part II	API
N. B. Galluzzo	IV-D-17, Part II IV-D-18, Part II	Monsanto Plastics and Resins Co. 800 N. Lindbergh Boulevard St. Louis, Missouri 63166
R. W. Russell	IV-D-23, Part II	Council on Wage and Price Stability Winder Building 600 17th Street, N.W. Washington, D.C. 20506
M. R. Foresman	IV-D-25, Part II	Monsanto Chemical Intermediates Co. 800 N. Lindbergh Boulevard St. Louis, Missouri 63166
D. E. Rickert	IV-F-2, Part II	Chemical Industry Institute of Toxicology (CIIT) P.O. Box 12445 Research Triangle Park, North Carolina 27709
R. D. Irons	IV-F-3, Part II IV-F-11, Part II	CIIT
D. Doniger	IV-F-4, Part II	Natural Resources Defense Council 1725 I Street, N.W., Suite 600 Washington, D.C. 20006
P. S. Hewett	IV-F-5, Part II	Reichhold Chemicals, Inc. 601-707 Woodward Heights Boulevard Detroit, Michigan 48220
D. Glassman	IV-F-6, Part II	USS Chemicals 600 Grant Street Pittsburgh, Pennsylvania 15230

(Continued)

TABLE 2-1. LIST OF COMMENTERS ON THE PROPOSED NATIONAL
EMISSION STANDARD FOR BENZENE EMISSIONS FROM MALEIC
ANHYDRIDE PLANTS (Continued)

Commenter	Docket No.	Affiliation
A. Meyer	IV-F-7, Part II	DENKA Chemical Corporation 8701 Park Place Boulevard P.O. Box 87220 Houston, Texas 77017
H. A. Jewett	IV-F-10, Part II	Private Citizen 5451 42nd Street, N.W. Washington, D.C. 20015

of IV-D-22). Monsanto has recently completed installation of a thermal oxidizer at its St. Louis maleic anhydride plant (Attachment E of IV-D-22).

Tenneco has registered its maleic anhydride plant with the New Jersey Department of Environmental Protection. The State will require Tenneco to install an incinerator or equivalent controls. Tenneco interprets this requirement as equivalent to 97 percent control and intends to comply (Attachment E of IV-D-22).

Response: At proposal, the Administrator determined that maleic anhydride process vents are a source category that should be regulated for two reasons: they emit significant amounts of benzene, and based on estimated maximum lifetime risk and number of leukemia cases, they ranked as one of the higher priority benzene source categories for regulation (Part I Docket Item II-I-99). These conclusions were based on the maleic anhydride industry's control status during the proposed standard's development.

At proposal, the following maleic anhydride plants were considered to be operating or operational:

- USS Chemicals, Neville Island, Pennsylvania;
- Reichhold Chemicals, Inc., Morris, Illinois;
- Reichhold Chemicals, Inc., Elizabeth, New Jersey;
- Ashland Chemical, Neal, West Virginia;
- DENKA Chemical Company, Houston, Texas;
- Koppers, Bridgeville, Pennsylvania;
- Koppers, Chicago, Illinois;
- Monsanto, St. Louis, Missouri (20 percent n-butane feedstock);
- Tenneco, Fords, New Jersey; and
- Amoco, Joliet, Illinois (n-butane feedstock).

In addition, several plants were considered to have process vent control devices with the following emission reduction capabilities:

- Koppers (Pennsylvania), 99 percent control from a waste heat boiler;
- DENKA, 97 percent control from a thermal incinerator;
- Reichhold, Morris, 90 percent control from a carbon adsorption unit;

- Reichhold, Elizabeth, 97 percent control from a carbon adsorption unit; and
 - USS Chemicals, 90 percent control from a catalytic incinerator.
- Finally, the proposal noted that the standard would also apply to one fumaric acid plant producing maleic anhydride as an intermediate product using a benzene feedstock. Health, environmental, energy, and economic impacts for this plant were not included in the proposal because EPA had only become aware of this plant just prior to proposal. This plant is owned by Pfizer, has a capacity of 12,800 Mg/yr (maleic acid), and is located in Terre Haute, Indiana. Maleic anhydride producers were initially identified by EPA through published commercial sales of maleic anhydride. Unlike other fumaric acid producers, which make both fumaric acid and maleic anhydride for sale (such as Monsanto and U.S. Steel), Pfizer produces only fumaric acid for sale. All the maleic acid it produces is used captively (Part II Docket Item IV-D-22). Because of this, it was not originally identified as a maleic anhydride producer in calculating impacts at proposal. However, it produces maleic acid with the same technology, air oxidation of benzene, as other maleic anhydride producers covered by the standard. Consequently, Pfizer's maleic anhydride production unit appropriately was covered by the proposed standard.

Based on information obtained prior to proposal, EPA made estimates of the health impact due to emissions from these plants. Commenters felt that these quantitative estimates show the risks to be insignificant and that the industry did not warrant regulation under Section 112.

Quantitative risk estimates at ambient concentrations involve an analysis of the effects of a substance in high-dose epidemiological or animal studies, and extrapolation of these high-dose results to relevant human exposure routes at low doses. In the case of benzene, the effects observed were the result of high-dose epidemiological studies. The mathematical models used for such extrapolations are based on observed dose-response relationships for carcinogens and assumptions about such relationships as the dose approaches very low levels or zero.

The risk to public health from carcinogenic emissions may be estimated by combining the dose-response relationship obtained from this carcinogenicity strength calculation with an analysis of the extent of population exposure to the substance through the ambient air. Exposure in

this context is a function of both a substance's concentration and duration.

The exposure analyses are based on air quality models, available emission estimates from maleic anhydride plants, and approximate population distributions near these sources. The air quality models used estimated exposures out to 20 kilometers from the source, and population and growth statistics were examined. Along with the existing carcinogenic strength determinations, the information collected was used to provide estimates of the degree of risk to individuals and the range of increased cancer incidence expected from ambient air benzene exposures associated with maleic anhydride plants at various possible benzene emission levels.

The estimated health impacts resulting from the proposed standard were bounded by a range. These ranges represent 95 percent confidence limits on two sources of uncertainty in the benzene risk estimates. One source derives from the variations in dose/response among the three occupational studies upon which the benzene unit risk factor is based. A second source involves the uncertainties in the estimates of ambient exposure. In the former case, the confidence limits are based on the assumption that the slopes of the dose/response relationships are unbiased estimates of the true slope and that the estimates are log normally distributed. In the latter case, the limits are based on the assumption that actual exposure levels may vary by a factor of two from the estimates obtained by dispersion modeling (assuming that the source-specific input data are accurate).

Other uncertainties associated with estimating health impacts are not quantified here. EPA has extrapolated the leukemia risks identified for occupationally exposed populations (generally healthy, white males) to the general population for whom susceptibility to a carcinogenic insult could differ. The presence of more or less susceptible subgroups within the general population would result in an occupationally-derived risk factor that may underestimate or overestimate actual risks. To the extent that there are more susceptible subgroups within the general population, the maximum individual lifetime risks may be underestimated.

On the other hand, general population exposures to benzene are much lower than those experienced by the exposed workers in the occupational studies, often by several orders of magnitude. In relating the

occupational experience to the general population, EPA has applied a linear, non-threshold model that assumes that the leukemia response is linearly related to benzene dose, even at very low levels of exposure. There are biological data supporting this approach, particularly for carcinogens. However, there are also data which suggest that, for some toxic chemicals, dose/response curves are not linear, with response decreasing faster than dose at low levels of exposure. At such levels, the non-linear models tend to produce smaller risk factors than the linear model. The data for benzene do not conclusively support either hypothesis. EPA has elected to use the linear model for benzene because this model is generally considered to be conservative compared to the non-linear alternatives. This choice may result in an overestimate of the actual leukemia risks.

EPA estimates ambient benzene concentrations in the vicinity of emitting sources through the use of atmospheric dispersion models. EPA believes that its ambient dispersion modeling provides a reasonable estimate of the maximum ambient levels of benzene to which the public could be exposed. The models accept emissions estimates, plant parameters, and meteorology as inputs and predict ambient concentrations at specified locations, conditional upon certain assumptions. For example, emissions and plant parameters often must be estimated rather than measured, particularly in determining the magnitude of fugitive emissions and where there are large numbers of sources. This can lead to overestimates or underestimates of exposure. Similarly, meteorological data often are not available at the plant site but only from distant weather stations that may not be representative of the meteorology of the plant vicinity.

EPA's dispersion models normally assume that the terrain in the vicinity of the sources is flat. For sources located in complex terrain, this assumption would tend to underestimate the maximum annual concentration although estimates of aggregate population exposure would be less affected. On the other hand, EPA's benzene exposure models assume that the exposed population is immobile and outdoors at their residence, continuously exposed for a lifetime to the predicted concentrations. To the extent that benzene levels indoors are lower and that people do not reside in the same area for a lifetime, these assumptions will tend to overpredict exposure.

Upon reconsideration, EPA has concluded that the presentation of the risk estimates as ranges does not offer significant advantages over the presentation as the associated point estimates of the risk. Further, the proposal ranges for benzene make risk comparisons among source categories more difficult and tend to create a false impression that the bounds of the risks are known with certainty. For these reasons, the benzene risks in this rulemaking are presented as point estimates of the leukemia risk. EPA believes that these risk numbers represent plausible, if conservative, estimates of the magnitude of the actual human cancer risk posed by benzene emitted from the source categories evaluated. For comparison, the proposal ranges may be converted into rough point estimates by multiplying the lower end of the range by a factor of 2.6.

The assumptions necessary to estimate benzene health risks and the underlying uncertainties have led some commenters on EPA's proposed rules to suggest that the risk estimates are inappropriate for use in regulatory decision making. Although EPA acknowledges the potential for error in such estimates, the Agency has concluded that both the unit risk factor for benzene and the evaluation of public exposure represent plausible, if conservative, estimates of actual conditions. Combining these quantities to produce estimates of the leukemia risks to exposed populations implies that the risk estimates obtained are also conservative in nature; that is the actual leukemia risks from benzene exposure are not likely to be higher than those estimated. In this context, EPA believes that such estimates of the health hazard can and should play an important role in the regulation of hazardous pollutants.

The control status of the maleic anhydride industry with regard to benzene has changed significantly since proposal. First, four plants have ceased operation permanently. Koppers shut down its Bridgeville, Pennsylvania, plant in March 1979 and has no plans to reactivate it for maleic anhydride production (Part II Docket Items IV-D-22, Attachment E, and II-I-38). Reichhold shut down its Elizabeth, New Jersey, plant in August 1979, from which pumps and other small equipment have been removed (Part II Docket Item IV-E-15), and its Morris, Illinois, plant around August 1982 (Part II Docket Item IV-E-15). Tenneco shut down its Fords, New Jersey, plant in October 1982 (Part II Docket Item IV-D-32). The Koppers, Illinois, plant no longer recovers maleic anhydride

as a by-product of its phthalic anhydride production (Part II Docket Items IV-E-17 and IV-E-22).

The largest source of uncontrolled benzene emissions, the Monsanto plant, has installed a thermal incinerator with a waste heat boiler that can achieve at least 97 percent control of benzene emissions (Part II Docket Item IV-E-12). Its installation is part of a Monsanto environmental control and energy conservation program. The device controls volatile organic compounds from either the n-butane-based or the benzene-based process (Part II Docket Item IV-D-22, Attachment E). Thirty percent of the plant's steam requirements are supplied by the maleic anhydride process. The Monsanto plant currently uses n-butane for 40 percent of its feedstock needs (Part II Docket Item IV-E-20) and plans to convert remaining capacity to n-butane by 1985 (Part II Docket Item II-I-42). Only one new plant has been constructed since proposal and it is 100 percent butane.

The DENKA plant currently is using n-butane for all of its capacity (Part II Docket Items IV-E-7 and IV-E-14). The Ashland plant has converted all of its capacity to n-butane (Part II Docket Items IV-E-8 and IV-E-13) and the USS Chemicals plant has converted part of its capacity to n-butane (Part II Docket Item IV-E-23). Only the Pfizer plant has not changed control status since proposal, using only benzene as a feedstock.

Industry commenters maintained that the reduced benzene emissions have resulted in significant decreases in associated health risks to the extent that regulation is no longer warranted. They considered the estimated health risks posed by benzene emissions from maleic anhydride process vents to be insignificant.

In view of the changes in the maleic anhydride industry following proposal of the standard, EPA examined the current emission levels, risks, and potential reductions that could be achieved to determine whether maleic anhydride process vents continue to pose a significant risk of leukemia and whether a benzene standard is warranted under Section 112.

Maleic anhydride process vents are now estimated to emit about 960 megagrams of benzene annually from the 3 plants that continue to use benzene as a feedstock (see Appendix A). This amount is less than 2 percent of total benzene emissions from stationary sources. Estimated lifetime risk due to these emissions is about 7.6×10^{-5} for the most

exposed individuals, and over the total exposed population (within 20 km of each plant) about 0.029 leukemia cases per year is estimated to occur. These current (or baseline) impacts are presented in Table 2-2. (The current impacts are actually smaller than estimated here, because they do not reflect some butane capacity at one of the plants. Because the company considered the amount of this capacity confidential, the actual estimates cannot be published. However, this information would not affect any regulatory decision.)

For comparison, at proposal, 8 plants were identified as benzene users, emitting 5,800 Mg/yr. These benzene emissions were estimated to result in about 0.46 leukemia cases per year and a maximum lifetime risk of about 2.3×10^{-4} . Thus, since proposal, benzene emissions have declined by over 80 percent, estimated annual leukemia incidence by over 90 percent, and maximum lifetime risk by over 60 percent.

Control techniques that can be applied to maleic anhydride process vents were discussed at proposal and include carbon adsorption, incineration, and feedstock substitution (from benzene to n-butane) which can reduce emissions by about 90, 97, and 100 percent, respectively, from uncontrolled vents. Although at proposal carbon adsorption was believed to be able to achieve 97 percent control at maleic anhydride plants, EPA has revised the estimated reduction to 90 percent because it has not been demonstrated the carbon adsorption can achieve 97 percent control on a maleic anhydride vent stream. Applying add-on control technologies of carbon adsorption or incineration could reduce nationwide benzene emissions from these sources by roughly 70 to 90 percent, primarily at one plant.

While all new process units are expected to be butane-based, the technological and economic ability to switch all existing process units is questionable, even though some have done so. This is primarily due to factors such as spatial restrictions (process equipment in a butane-based plant must be about 40 percent larger to produce the same capacity as a benzene-based plant) or the inability to develop n-butane technology, which is relatively new and highly proprietary. However, the trend in recent years for existing plants has been to switch to butane because of its economic superiority. This trend is expected to continue, with at least one plant planning to convert its remaining capacity to butane in the near future.

TABLE 2-2. CURRENT ESTIMATED IMPACTS

Plant	Benzene emissions (Mg/yr)	Leukemia incidence (cases/yr)	Maximum lifetime risk (x 10 ⁻⁶)
Koppers, PA ^a	NA		
Reichhold, NJ ^a	NA		
Pfizer, IN ^b	780	0.005	76
Ashland, WY ^c	0		
Tenneco, NJ ^a	NA		
Reichhold, IL ^a	NA		
USS Chemicals, PA	130	0.015	11
DENKA, TX ^c	0		
Monsanto, MO	53	0.009	3.2
Monsanto, FL	0		
Amoco, IL	0		
Total	960 ^d	0.029	

^aClosed since proposal.

^bFumaric acid plant not included at proposal.

^cPlant converted to n-butane since proposal.

^dRounded to two significant figures.

The current estimated incidence and maximum lifetime risk represent small risks to public health. By both expressions of health risk, the extent of the hazard posed by this source category is more than an order of magnitude smaller than for benzene source categories for which standards are being developed. Additionally, the estimated impact on nationwide leukemia incidence of further control would be small, ranging from roughly 0.024 to 0.016 cases per year, or a reduction of about 17 to 45 percent over baseline, depending on the control technology used (carbon adsorption or incineration). Maximum lifetime risk could be reduced to roughly 5.2×10^{-6} to 1.1×10^{-5} . While a larger percentage reduction can be achieved in maximum lifetime risk (about 80 to 90 percent), the absolute amount is also small.

Therefore, in light of the extent of control now exhibited by the industry, the small portion (less than 2 percent) of total benzene emissions from stationary sources that maleic anhydride process vent emissions represent, the trends to discontinue benzene use at existing plants and to use only n-butane at new plants, the small leukemia incidence and maximum lifetime risk estimated at current levels, and the small incremental reductions in health risks achievable with add-on control technologies, the Administrator has concluded that benzene emissions from maleic anhydride process vents do not warrant federal regulatory action under Section 112.

2.1.2 Priority of Regulating Source Categories

Comment: One commenter felt that EPA had not ordered its priorities properly and was attempting to regulate first one of the smaller sources of risk due to benzene emissions (Part II Docket IV-D-5). Conversely, another felt that control of all benzene emissions should be given high priority (Part II Docket Item IV-D-9).

Response: Initially, after benzene was listed in 1977 as a hazardous air pollutant (42 FR 29332), standards development for all stationary benzene source categories was given high priority. As more information was gathered, it became apparent that some source categories emit much smaller amounts of benzene than others, indicating that some posed less relative risk than others. Consequently, to use resources better, the Agency arranged source categories by priority in terms of estimated maximum risk

and leukemia incidence. This was an ordinal ranking to establish comparative health risks among source categories. This ordering identified source categories presenting greater relative risk for which regulatory efforts should proceed immediately. This estimation ranked maleic anhydride process emissions as one of the higher priority source categories for regulation (Part I Docket Item II-I-99).

Because industry changes (see Subsection 2.1.1) have substantially decreased estimated maximum lifetime risk and leukemia incidence, and likewise the potential reductions in health risk, the Administrator has concluded that maleic anhydride process vents no longer warrant regulation at the federal level (see Subsection 2.1.1).

2.1.3 Risk Estimate Consideration

Comment: After recalculating the number of leukemia cases per year due to benzene emissions from maleic anhydride process vents as 0.079, one commenter (Part II Docket Item IV-D-22) considered this number close enough to the number of leukemia cases that EPA deemed reasonable at proposal to say that no regulation was necessary.

Response: The Agency has reestimated the number of leukemia cases per year at current baseline levels to be about 0.029 cases per year. This incidence in conjunction with other factors (see Response 2.1.1) persuaded the Administrator that a federal regulation was not warranted.

2.1.4 Generic Benzene Standard

Comment: One commenter supported postponement of a standard for benzene emissions from maleic anhydride plants until it can be incorporated into a larger, general benzene emissions standard (Part II Docket Item IV-D-15).

Response: The numerous source categories, their varying characteristics, and the resulting different methods to control each source's emissions make a general benzene emission standard infeasible. As discussed previously, the Administrator has concluded that a federal standard for maleic anhydride process vents is not warranted.

2.1.5 Fugitive and Storage Emissions

Comment: According to one commenter, division of process, fugitive, and storage emissions into separate documents is confusing and makes comparison of appropriate information difficult (Part II Docket IV-D-19).

Response: Because various sources emit benzene, categories were established according to similar emission characteristics and applicable

control technology. Although benzene fugitive and storage emissions at maleic anhydride plants could have been analyzed along with maleic anhydride process vents, any standards would have been specific only to fugitive and storage sources at maleic anhydride plants. To cover all benzene fugitive and storage sources, EPA would have had to propose identical fugitive and storage standards for each kind of chemical plant and refinery using or making benzene. To avoid this redundancy, to develop standards more efficiently, and to cover all like benzene fugitive and storage sources with uniform requirements, EPA proposed standards for these sources separately from those for process vents and applied them to several source categories (46 FR 1165 and 45 FR 83952).

2.1.6 Existing Applicable Standards

Comment: One commenter said the proposed standard would have little health impact because a standard for organic emissions from existing chemical plants will control VOC emissions to nearly the level of the proposed standard (Part II Docket Item IV-D-14).

Response: As discussed previously, based in part on the current levels of control in the industry, the Administrator has decided not to issue federal regulations for maleic anhydride process vents.

2.2 HEALTH AND ENVIRONMENTAL IMPACTS

2.2.1 Dispersion Modeling

Comment: The dispersion model used by Cramer, unlike the model developed by CMA, fails to consider site-specific factors, according to one commenter (Part II Docket Item IV-D-22, Attachment E). Specific factors that cause the models to differ include:

- Variations in product recovery absorber (PRA) emission rates, Cramer used 2.34×10^{-3} g/s per MT/yr; CMA used an estimated industry average of 1.86×10^{-3} .
- Variations in stack height. Cramer used 27.4 meters; four plants have higher stacks.
- Variations in meteorological data. Cramer used worst-case data for Pittsburgh; CMA data reflected local conditions over an entire year.
- Variations in storage emissions. Cramer assumed storage sources to be uncontrolled; CMA took account of existing controls on storage sources.

Response: Prior to proposal, EPA did not have enough information on each plant to perform a detailed modeling analysis. However, such an analysis is neither necessary for developing proposed standards nor for estimating the resulting impacts. One or more model plants representing "typical" plants in the industry are developed that serve as surrogates when comprehensive information is not available. Such model plants have served well as estimates in the past and will do so in the future as long as more complete data are unavailable, or the resources to perform detailed analyses become exorbitant relative to the benefits derived.

However, when more thorough information is obtained, usually through public comments, a more accurate analysis can be performed. This is the case with maleic anhydride plants.

Based on much more detailed emissions data than it had at proposal, EPA has substantially refined the dispersion modeling. Since proposal, EPA has modeled each plant individually, based on the emissions data supplied by the CMA during the public comment period. The revised modeling also takes into consideration variations in stack parameters and uses meteorological data from STAR* stations near the plants. Since only process emissions were considered in the promulgated standards, variation in storage emissions was not a factor in the revised modeling. A more detailed description can be found in Appendix B.

2.2.2 Current Health Impact

Comment: Because of changes in the maleic anhydride industry (see Subsection 2.1.1), one commenter (Part II Docket Item IV-F-8, p. 9-12) contended that EPA's estimate of 0.496 leukemia case per year under current control conditions is too high and the correct estimate is 0.0037 leukemia case per year based on:

- Installation of 97 percent control at the Monsanto and Tenneco plants,
- Closure of the Koppers (Pennsylvania) and Reichhold (New Jersey) plants,
- Use of a 97-percent conversion rate for the Ashland plant,

*STAR (stability array) data are standard climatological frequency of occurrence summaries formulated for use in EPA models and are available for major U.S. sites from the National Climatic Center, Asheville, North Carolina. The data consist of frequencies tabulated as functions of wind speed stability and wind direction classes.

- Use of plant-specific data in dispersion modeling, and
- Use of the Lamm risk factor (0.031 death/10⁶ ppb-person-years).

Response: As discussed in the previous response, the dispersion modeling has been revised to account for the current operating and control status of the industry and for the plant-specific data provided by CMA. The results are contained in Appendix B.

EPA has reviewed the comments regarding its unit risk factor and the Lamm unit risk factor. In light of the comments, the Agency has revised its unit risk factor accordingly, although not to the extent desired by the commenter. The revised unit risk factor is lower by about 7 percent.

Based on the revised dispersion modeling and the Carcinogen Assessment Group's revised unit risk factor, the Agency has recalculated the estimated leukemia incidence and maximum lifetime risk under assumed current control levels (see Appendix B). The leukemia incidence is estimated to be about 0.029 cases per year. The maximum lifetime risk is estimated to be about 7.6×10^{-5} .

2.2.3 Risk and Expected Plant Life

Comment: One commenter stated that calculation of estimated lifetime risks and estimated leukemia cases per year should include consideration of existing sources' expected operating lifetimes (Part II Docket Item IV-D-8).

Response: No expected standard operating lifetime for maleic anhydride plants has been determined (Part II Docket Item IV-D-22). The approximate risk and leukemia incidence for any time period can be obtained by prorating the maximum risk and leukemia incidence values. pollution controls (Part II Docket Item III-B-1). Because of this uncertainty, however, emissions from all existing plants were used to determine impacts. The current analysis accounts for plant closures that have been confirmed, such as those of Koppers, Reichhold, and Tenneco. Health benefits due to closure are elimination of illnesses, including leukemia, related to benzene exposure from those plants.

2.2.4 Population "At Risk"

Comment: EPA gave no explanation for choosing a 20-kilometer radius for assessing human health impacts (Part II Docket Item IV-D-8).

Response: The reason for estimating exposure to within 20 kilometers of stationary sources is based primarily on modeling considerations. Twenty kilometers was chosen as a practical modeling stop-point. The results of dispersion models are felt to be reasonably accurate within that distance. The dispersion coefficients used in modeling are based on empirical measurements made within 10 kilometers of sources. These coefficients become less applicable at long distances from the source, and the modeling results become more uncertain.

APPENDIX A
BASELINE EMISSIONS CALCULATIONS

A.1 INTRODUCTION

This appendix summarizes baseline process benzene emissions from maleic anhydride process vents and presents the methodology used to estimate these emissions.

A.2 EMISSIONS CALCULATIONS

Table A-1 presents baseline benzene process emissions, as well as the parameters used to estimate these emissions for each plant. Though the Chemical Manufacturers Association (CMA) provided process vent emission rates (Part II Docket Item IV-F-8), the basis for these estimates was not clearly described. Total nationwide process vent benzene emissions derived from the industry emission rates are 1,010 Mg/yr, or only about 5 percent more than EPA's estimate of 960 Mg/yr. Therefore, the emissions were calculated using the following equation, developed at proposal and used to calculate the emissions at proposal.

$$\text{Emissions Mg/yr} = 1 - \text{control efficiency} \times \frac{190 \text{ kg}}{\text{hr}} \times \frac{8,000 \text{ hr}}{\text{yr}} \times \frac{\text{plant capacity}}{22,700 \text{ Mg/yr}} \\ \times \frac{100 - \text{benzene conversion rate}}{100 - 94.5} \times \frac{1 \text{ Mg}}{1,000 \text{ kg}}$$

Control efficiencies were obtained from industry sources (Part II Docket Items IV-E-10 and IV-E-18). The emission rate 190 kg/hr and corresponding plant capacity 22,700 Mg/yr and benzene conversion rate (94.5 percent) represent Enviroscience's model plant (Part II Docket Item II-A-007). Plant capacities were available from literature sources (Part II Docket Items II-I-010 and IV-J-20). EPA assumed the average conversion rates of the plants were those provided by the industry (Part II Docket Item IV-D-22). For Monsanto, which provided a range of 93 to 97, an average conversion rate of 95 percent was assumed. The emission estimates are based on 100 percent production capacity. In fact, these plants are operating well below rated capacity, and thus actual emissions are lower. (Note: USS Chemicals has converted some of its capacity to butane

TABLE A-1. BASELINE BENZENE PROCESS EMISSIONS

Plant and location	Capacity ^a (Mg/yr)	Benzene conversion rate ^b (%)	Current control efficiency ^c (%)	Baseline benzene process emissions (Mg/yr)
Koppers, PA ^d	15,400	NA	NA	NA
Reichhold, NJ ^d	13,600	NA	NA	NA
Pfizer, IN ^e	12,800	95	0	780
Ashland, WV ^f	27,200	NA	NA	0
Tenneco, NJ ^d	11,800	NA	NA	NA
Reichhold, IL ^d	20,000	NA	NA	NA
USS Chemicals, PA	36,400	97	90	130
DENKA, TX ^f	22,700	NA	NA	0
Monsanto, MO	28,600 ^g	95	97	53
Monsanto, FL	59,000	NA	NA	0
Amoco, IL	27,000	NA	NA	0
Total	274,500			960 ^h

^aPart II Docket Items II-I-010 and IV-J-20.

^bPart II Docket Item IV-D-22.

^cPart II Docket Items IV-E-10 and IV-E-18.

^dplant closed permanently since proposal.

^eFumaric acid plant not included at proposal.

^fBoth plants have converted to n-butane production.

^gThis represents 60 percent of the total plant capacity. The rest of the MA is produced from n-butane.

^hEmission total rounded to two significant figures.

feedstock. However, because the percent capacity it has converted has not been made public and because consideration of the amount of product made from butane would only lower the emission estimates slightly, all production was assumed to be from benzene).

APPENDIX B
METHODOLOGY FOR ESTIMATING LEUKEMIA INCIDENCE AND MAXIMUM
LIFETIME RISK FROM EXPOSURE TO BENZENE EMISSIONS FROM
MALEIC ANHYDRIDE PROCESS VENTS

B.1 INTRODUCTION

The purpose of this appendix is to describe the methodology and to provide the information used to estimate leukemia incidence and maximum lifetime risk from population exposure to benzene emissions from maleic anhydride process vents. The methodology consists of four major components: estimating annual average concentration patterns of benzene in the region surrounding each plant, estimating the population associated with each computed concentration, computing exposure by summing the products of the concentrations and associated populations, and estimating annual leukemia incidence and maximum lifetime risk from exposure and concentration estimates. Due to the assumptions made in each of these four steps of the methodology, there is considerable uncertainty associated with the lifetime individual risk and leukemia incidence numbers calculated in this appendix. These uncertainties are explained in Section B.6 of this appendix.

B.2 ATMOSPHERIC DISPERSION MODELING

The long-term version of the Industrial Source Complex (ISCLT) dispersion model¹ was used to estimate annual average benzene concentrations in the vicinity of three maleic anhydride plants.

Seasonal or annual stability array (STAR) summaries are principal meteorological input to the ISCLT dispersion model. STAR data are standard climatological frequency of occurrence summaries formulated for use in EPA models and available for major U.S. sites from the National Climatic Center, Asheville, N.C. A STAR summary is a joint frequency of occurrence of wind speed stability and wind direction categories, classified according to the Pasquill stability categories. For this modeling analysis, seasonal STAR summaries were used. Urban mixing heights and rural mixing heights were used for plants in urban and rural areas,

respectively. The ISCLT dispersion model also required user input of ambient temperatures by stability category and mixing heights by stability and wind speed categories, for each season. Seasonal temperature and mixing height input data were computed by averaging hourly CRSTER meteorological preprocessor data for each category.

The model receptor grid consists of 10 downwind distances located along 16 radials. The radials are separated by 22.5° intervals beginning with 0.0° and proceeding clockwise to 337.5°. The 10 downwind distances for each radial are 0.2, 0.3, 0.5, 0.7, 1.0, 2.0, 5.0, 10.0, 15.0, and 20.0 kilometers. For plants with only one stack, the stack was assumed to be at the center of the receptor grid. For the U.S. Steel plant with two sources, stacks 502 and 1602 (see Section B.5.1) were assumed to be at the center of the receptor grid and stacks 501 and 1601 assumed to be 61 meters southeast of the grid center.

The ISCLT output for all plants modeled, consisting of annual concentration estimates at all 160 receptors, is contained in the docket (Part II, Docket item IV-J-16). ISCLT dispersion model concentration estimates have been found to be within a factor of two of measured concentrations in most tests.²

B.3 POPULATION AROUND MALEIC ANHYDRIDE PLANTS

The human exposure model (HEM)³ was used to estimate the population that resides in the vicinity of each receptor coordinate surrounding each maleic anhydride plant. A slightly modified version of the "Master Enumeration District List-- Extended" (MED-X) data base is contained in the HEM and used for population pattern estimation. This data base is broken down into enumeration district/block group (ED/BG) values. MED-X contains the population centroid coordinates (latitude and longitude) and the 1970 population of each ED/BG in the United States (50 States plus the District of Columbia). For human exposure estimations, MED-X has been reduced from its complete form (including descriptive and summary data) to produce a randomly accessible computer file of the data necessary for the estimation. A separate file of county-level growth factors, based on the 1978 estimates of 1970 to 1980 growth factor at the county level, has also been created for use in estimating 1980 population figures for each ED/BG. The population "at risk" to benzene exposure was considered to be persons residing within 20 km of maleic anhydride plants. The population around each plant was identified by specifying the geographical coordinates of that plant.

B.4 POPULATION EXPOSURE METHODOLOGY

B.4.1 Exposure Methodology

The plant's geographical coordinates and the concentration patterns computed by the ISCLT were used as input to the HEM. (The HEM also has its own atmospheric dispersion model. However, the HEM dispersion model, still under development, is not as detailed as the ISCLT.)

For each receptor coordinate, the concentration of benzene estimated by the ISCLT and the population estimated by the HEM to be exposed to that particular concentration are identified. The HEM multiplies these two numbers to produce population exposure estimates and sums these products for each plant. A two-level scheme has been adopted in order to pair concentrations and populations prior to the computation of exposure. The two-level approach is used because the concentrations are defined on a radius-azimuth (polar) grid pattern with nonuniform spacing. At small radii, the grid cells are much smaller than ED/BG's; at large radii, the grid cells are much larger than ED/BG's. The area surrounding the source is divided into two regions, and each ED/BG is classified by the region in which its centroid lies. Population exposure is calculated differently for the ED/BG's located within each region.

For ED/BG centroids located between 0.1 km and 2.8 km from the emission source, populations are divided between neighboring concentration grid points. There are 96 (6 x 16) polar grid points within this range. Each grid point has a polar sector defined by two concentric arcs and two wind direction radials. Each of these grid points is assigned to the nearest ED/BG centroid identified from MED-X. The population associated with the ED/BG centroid is then divided among all concentration grid points assigned to it. The exact land area within each polar sector is considered in the apportionment.

For population centroids between 2.8 km and 20 km from the source, a concentration grid cell, the area approximating a rectangular shape bounded by four receptors, is much larger than the area of a typical ED/BG (usually 1 km in diameter). Since there is a linear relationship between the logarithm of concentration and the logarithm of distance for receptors more than 2 km from the source, the entire population of the ED/BG is assumed to be exposed to the concentration that is geometrically interpolated radially and arithmetically interpolated azimuthally from the four receptors bounding the grid cell.

Concentration estimates for 80 (5 x 16) grid cell receptors at 2.0, 5.0, 10.0, 15.0, and 20.0 km from the source along each of 16 wind directions are used as reference points for this interpolation.

In summary, two approaches are used to arrive at coincident concentration/population data points. For the 96 concentration points within 2.8 km of the source, the pairing occurs at the polar grid points using an apportionment of ED/BG population by land area. For the remaining portions of the grid, pairing occurs at the ED/BG centroids themselves, through the use of log-log and linear interpolation. (For a more detailed discussion of the methodology used to estimate exposure, see Reference 3.)

B.4.2 Total Exposure

Total exposure (persons- $\mu\text{g}/\text{m}^3$) is the sum of all multiplied pairs of concentration-population computed by the previously discussed methodology:

$$\text{Total exposure} = \sum_{i=1}^N (P_i C_i) \quad (1)$$

where

- P_i = population associated with point i ,
- C_i = annual average benzene concentration at point i , and
- N = total number of polar grid points between 0 and 2.8 km and ED/BG centroids between 2.8 and 20 km.

The computed total exposure is then used with the unit risk factor to estimate leukemia incidence and maximum lifetime individual risk. This methodology is described in the following sections. (Note: "Exposure" as used here is the same as "dosage" in the computer printout, docket item IV-J-16.)

B.4.3 Unit Risk Factor

The unit risk factor (URF) for benzene is 9.9×10^{-8} (leukemia cases per year)/($\mu\text{g}/\text{m}^3$ -person years), as calculated by EPA's Carcinogen Assessment Group (CAG). This factor is slightly lower than the factor derived by CAG at proposal. Arguments have been advanced that the assumptions made by EPA (CAG) in the derivation of a unit leukemia risk factor for benzene represented "serious misinterpretation" of the underlying epidemiological evidence. Among the specific criticisms are: CAG (1) inappropriately included in

its evaluation of the Infante et al. study two cases of leukemia from outside the cohort, inappropriately excluded a population of workers that had been exposed to benzene, and improperly assumed that exposure levels were comparable with prevailing occupational standards; (2) accepted, in the Aksoy et al. studies, an unreasonable undercount of the background leukemia incidence in rural Turkey, made a false adjustment of age, and under-estimated the exposure duration; and (3) included the Ott et al. study in the analysis despite a lack of statistical significance.

EPA has reexamined and reevaluated each of the three studies. In summary, EPA concluded that one case of leukemia was inappropriately included from the Infante et al. study in computing the original unit risk factor. Additionally, EPA reaffirmed its decision to exclude dry-side workers from that study in developing the risk factor. The Agency agrees that the Aksoy et al. study was adjusted improperly for age; however, the exposures and durations of exposures are still considered reasonable estimates. The Ott et al. study was not eliminated from the risk assessment because the findings meet the test of statistical significance and because it provides the best documented exposure data available from the three epidemiological studies.

Based on these findings, the unit risk factor (the probability of an individual contracting leukemia after a lifetime of exposure to a benzene concentration of one part benzene per million parts air) was recalculated. The revised estimate resulted in a reduction of about 7 percent from the original estimate of the geometric mean, from a probability of leukemia of 0.024/ppm⁴ to a probability of leukemia of 0.022/ppm.

B.4.4 Calculation of Estimated Annual Leukemia Incidence

The annual leukemia incidence associated with a given plant under a given regulatory alternative is the product of the total exposure around that plant in $\mu\text{g}/\text{m}^3$ -persons and the unit risk factor, 9.9×10^{-8} . Thus,

$$\text{Annual leukemia incidence} = (\text{total exposure}) \times (\text{unit risk factor}), \quad (2)$$

where total exposure is calculated according to Equation 1.

B.4.5 Calculation of Maximum Lifetime Risk

The populations in areas surrounding maleic anhydride plants have various risk levels of leukemia incidence from exposure to benzene emissions. Using the maximum annual average concentration of benzene to which any person is exposed, it is possible to calculate the maximum lifetime risk of leukemia (lifetime probability of leukemia to persons exposed to the highest concentration of benzene) attributable to benzene emissions using the following equation:

$$\text{Maximum lifetime risk} = C_{i,\text{max}} \times (\text{URF}) \times 70, \quad (3)$$

where

$C_{i,\text{max}}$ = the maximum annual average concentration at any receptor location where exposed persons reside,

URF = the unit risk factor, 9.9×10^{-8} , and

70 years = average individual's life span.

B.5 LEUKEMIA INCIDENCE AND MAXIMUM LIFETIME RISK

B.5.1 Input Data, Assumptions, and Methodology

Population exposures were computed for several different control scenarios for each plant in order to estimate the leukemia incidence and maximum lifetime risk at the current level of control.

These emission scenarios consisted of: (1) no control device (also the assumed startup mode), (2) properly operating (meeting the assumed current control level) control device, and (3) malfunction. The emission rates and other dispersion model inputs are shown in Table B-1. The original emission rates supplied by industry (Part II Docket Item IV-F-8) were adjusted for the modeling to conform with assumptions made at proposal concerning conversion rates. The modeling results reflect these adjustments. However, it was determined after the modeling was performed that such adjustments were unnecessary. Rather than repeat the modeling effort, the results were prorated using a ratio of the emission rates supplied by industry (Part II Docket Item IV D-22) to those that were actually modeled. These results were subsequently used in calculating the health impacts. The corrected emission rates are shown in Table B-2. Table B-2 also reflects changes since proposal in published butane

TABLE B-1. PLANT SPECIFIC CHARACTERISTICS

Plant	Control Scenario	ISC model source no.	Emission rate (g/s)	Stack height (m)	Exit velocity (m/s)	Exit temperature ($^{\circ}$ K)	Diameter (m)
U.S. Steel	CI malfunction, NCD	501	30.24	33.5	10.0	317	1.68
		502	18.9	33.5	9.1	317	1.37
U.S. Steel	90% (CI)	1,601	10.08	33.5	18.6	589	1.68
		1,602	6.30	33.5	17.0	589	1.37
Monsanto	TI malfunction	3	82.9	45.7	16.4	317	2.134
		11	82.9	24.5	44.2	317	0.915
		9	2.64	45.7	16.4	404	2.134
Pfizer	NCD	13	22.05	23.2	41.2	316	0.610

TI = thermal incineration.

CI = catalytic incineration.

CA = carbon adsorption.

NCD = no control device.

TABLE B-2. ADJUSTED BENZENE EMISSION RATES

PLANT	CONTROL SCENARIO	PERCENT CONVERSION RATE ¹	EMISSION RATE, g/s
U.S. Steel	90% (CI)	97	7.371
	NCD, CI Malfunction	97	73.71
Monsanto	97% (TI)	95 ²	1.98
	NCD	95 ²	66
	TI Malfunction	95 ²	66
Pfizer	NCD	95	22.05

TI = Thermal Incineration
 CI = Catalytic Incineration
 CA = Carbon Adsorption
 NCD = No Control Device

¹ Conversion rates supplied by industry in Part II Docket Item IV-D-22.

² Average of operating range of 93 to 97 percent reported in Part II Docket Item IV-D-22.

capacity in the industry. It should also be noted that the CAG URF was revised after proposal to 9.9×10^{-8} from 1.06×10^{-7} . Plant location and meteorological inputs are provided in Table B-3. Total exposure for each plant under each scenario is shown in Table B-4. The exposure ($\text{person-}\mu\text{g}/\text{m}^3$) calculated for each scenario was then prorated according to the estimated hours per year a given plant would operate under that scenario. The adjusted exposures for each plant were used in estimating the exposure associated with the current level of control.

Based on information from two currently controlled maleic anhydride plants,^{5,6} the hours per year a plant would be under each scenario were estimated. Three total production unit startups with 8 hours of uncontrolled emissions each and 15 single-reactor startups with 1.5 hours of uncontrolled emissions each were assumed for a total estimate of 46.5 hours of startup emissions per year. Twenty malfunctions with 6 hours (maximum allowable time for excess emissions from malfunctions) of uncontrolled emissions each were assumed for a total estimate of 120 hours of malfunction emissions per year. Each plant was assumed to operate at full capacity with no control for both startup and malfunction emissions. The plant was assumed to operate properly for the remainder of an 8,000-hour operating year, or 7,833.5 hours. Population exposure for each plant under each regulatory alternative was then calculated as follows:

$$\text{Population exposure} = \frac{46.5}{8,000} S + \frac{120}{8,000} M + \frac{7,833.5}{8,000} P, \quad (4)$$

where

S = exposure from startup (Table B-4),

M = exposure from malfunction (Table B-4), and

P = exposure from proper control device operation under each regulatory alternative (Table B-4).

Population exposure in Table B-4 was multiplied by the CAG leukemia risk factor of 9.9×10^{-8} (see Equation 2) to estimate the annual leukemia incidence for each plant.

A similar computation is made for determining maximum lifetime risk. The maximum annual average benzene concentration under each scenario was prorated the same way as described above for the exposure calculation. Estimated maximum annual average concentrations for each plant under each scenario are shown also in

B-3. PLANT LOCATIONS AND METEOROLOGICAL INPUTS

Plant	Location	Latitude	Longitude	Urban or rural mixing heights	Seasonal STAR Summary	CRSTER model	
						meteorologically prepared data used for ambient temperature mixing height determinations	Surface data Upper air data
U.S. Steel	Neville Island, PA	40.5000	80.0833	Urban	Pittsburgh, Pa 1 hr data 1973-77	Pittsburgh, PA 1974	Pittsburgh, PA 1974
Monsanto	St. Louis, MO	38.5833	90.2000	Urban	St. Louis, MO 3 hr data 1973-77	St. Louis, MO 1977	Salem, IL 1977
Pfizer	Terre Haute, IN	39.3650	87.4150	Rural	Indianapolis, IN 1 hr data 1973-77	Indianapolis, IN 1977	Patterson, OH 1977

TABLE B-4. EXPOSURE AND MAXIMUM ANNUAL AVERAGE CONCENTRATIONS

Plant	Case	Total Exposure ($\mu\text{g}/\text{m}^3$ - person)	Maximum Annual Average Concentrations ($\mu\text{g}/\text{m}^3$)
U.S. Steel	NCD, CI Malfunction	1,830,000	35.0
	CI (90 percent)	120,000	0.932
Pfizer	NCD	50,800	11.0
Monsanto	NCD	2,730,000	27.3
	TI Malfunction	1,930,000	8.775
	TI (97 percent)	47,300	0.173

NCD = No control device; equivalent to startup emissions for situations in which a plant has a control device.

TI = Thermal incinerator.

CI = Catalytic incinerator.

CA = Carbon adsorber.

Table B-4. These, in turn, were used in estimating the maximum annual average concentration for each plant for each alternative as follows:

$$C_{i,max} = \frac{46.5}{8,000} C_{i_s,max} + \frac{120}{8,000} C_{i_M,max} + \frac{7,833.5}{8,000} C_{i_p,max} \quad (5)$$

where

$C_{i,max}$ = maximum annual average concentration for a plant under a given regulatory alternative,

$C_{i_s,max}$ = maximum annual average concentration during startup (Table B-4),

$C_{i_M,max}$ = maximum annual average concentration during malfunction (Table B-4), and

$C_{i_p,max}$ = maximum annual average concentration during proper control device operation (Table B-4).

Maximum lifetime risk for a given plant can be found by multiplying the maximum annual average concentration by the unit risk factor of 9.9×10^{-8} times 70 years (to obtain a lifetime estimate)(see Equation 3). The maximum lifetime risk for the industry is that due to the plant with the highest estimated maximum lifetime risk in the industry.

B.5.2 Example Calculations

B.5.2.1 Leukemia incidence. As an example for calculating leukemia incidence, the U.S. Steel plant is used. The population exposure is computed according to Equation 4 as follows:

$$\text{Population exposure} = \frac{46.5}{8,000} (1,830,000) + \frac{120}{8,000} (1,830,000) + \frac{7,833.5}{8,000} (120,000)$$

$$\text{Population exposure} = 156,000 \text{ person-}\mu\text{g/m}^3.$$

Therefore, the annual leukemia incidence (from Equation 2) is:

$$\text{Annual leukemia incidence} = 156,000 \times 9.9 \times 10^{-8}$$

$$\text{Annual leukemia incidence} = 0.015.$$

B.5.2.2 Maximum Lifetime Risk. Again, U.S. Steel is used to illustrate the calculation. The maximum annual average concentration as defined by Equation 5 is as follows:

$$C_{i,max} = \frac{46.5}{8,000} (35.0) + \frac{120}{8,000} (35.0) + \frac{7,833.5}{8,000} (90.932)$$

$$C_{i,max} = 1.64 \text{ } \mu\text{g}/\text{m}^3.$$

Maximum lifetime risk according to Equation 3 is as follows:

$$\text{Maximum lifetime risk} = 1.64 \times 9.9 \times 10^{-8} \times 70$$

$$\text{Maximum lifetime risk} = 1.1 \times 10^{-5}$$

B.5.3 Summary of Impacts

The methodology for calculating leukemia incidence and maximum lifetime risk (described in Section B.5.1) was extended to each plant for the current level of control. The estimated annual leukemia incidence is shown in Table B-5. The estimated nationwide leukemia cases per year under the estimated current level of control is about 0.029. The estimated maximum lifetime risk is shown in Table B-6. The estimated maximum lifetime risk under the estimated current level of control is about 7.6×10^{-5} .

B.6 UNCERTAINTIES

Estimates of both leukemia incidence and maximum lifetime risk are primarily functions of estimated benzene concentrations, populations, the unit risk factor, and the exposure model. The calculations of these variables are subject to a number of uncertainties of various degrees. Some of the major uncertainties are identified below.

B.6.1 Benzene Concentrations

Modeled ambient benzene concentrations depend upon: (1) plant configuration; (2) emission point characteristics, which can be different from plant to plant; (3) emission rates which may vary over time, and from plant to plant; and (4) meteorology, which is seldom available for a specific plant. The particular

TABLE B-5. ESTIMATED ANNUAL LEUKEMIA INCIDENCE ($\times 10^{-2}$)

Plant	Baseline
U.S. Steel	1.5
Pfizer	0.5
Monsanto	0.9
Total	2.9

TABLE B-6. ESTIMATED MAXIMUM LIFETIME RISK ($\times 10^{-6}$)

Plant	Baseline
U.S. Steel	11
Pfizer	76
Monsanto	3.2

dispersion model used can also influence the numbers. Using a different dispersion model, even with the same emission data input, can produce different results. The dispersion modeling also assumes that the terrain in the vicinity of the source is flat. For sources located in complex terrain, the maximum annual concentration could be underestimated by several fold due to this assumption. Assuming the inputs to the dispersion model are accurate, the predicted benzene concentrations are considered to be accurate to within a factor of 2.

B.6.2 Exposed Populations

Several simplifying assumptions were made with respect to the assumed exposed population. The location of the exposed population depends on the accuracy of the census data in the HEM. In addition, the exposed population is assumed to be immobile, remaining at the same location 24 hours per day, 365 days per year, for a lifetime (70 years). This assumption may be counterbalanced to some extent (at least in the calculation of incidence) by the assumption that no one moves into the exposure area either permanently as a resident or temporarily as a transient. The population "at risk" was assumed to reside within 20 km of each plant, regardless of the estimated concentration at that point. The selection of 20 km is considered to be a practical modeling stop-point. The results of dispersion modeling are felt to be reasonably accurate within that distance. The dispersion coefficients used in modeling are based on empirical measurements made within 10 kilometers of sources. These coefficients become less applicable at long distances from the source, and the modeling results become more uncertain. A numerical estimate of the accuracy of these assumptions regarding the exposed population is not available.

B.6.3 Unit Risk Factor

The unit risk factor contains uncertainties associated with the occupational studies of Infante, Aksoy, and Ott, and the variations in the dose/response relationships among the studies. Other uncertainties regarding the occupational studies and the workers exposed that may affect the unit risk factor were raised during the public comment period and focus on assumptions and inconclusive data contained in the studies. However, those uncertainties have not been quantified.

B.6.4 Other Uncertainties

There are several other uncertainties associated with estimating health impacts. Maximum lifetime risk and annual leukemia incidence were calculated based on a no-threshold linear extrapolation of leukemia risk associated with a presumably healthy white male cohort of workers exposed to benzene concentrations in the parts per million range compared to the risk associated with the general population, which includes men, women, children, nonwhites, the aged, and the unhealthy, who are exposed to concentrations in the parts per billion range. It is uncertain whether these widely diverse segments of the population have susceptibilities to leukemia that differ from that of workers in the studies. Furthermore, while leukemia is the only benzene health effect considered in these calculations, it is not the only possible health effect. Other health effects, such as aplastic anemia and chromosomal aberrations, are not as easily quantifiable and are not reflected in the risk estimates. Although these other health effects have been observed at occupational levels, it is not clear if they can result from ambient benzene exposure levels. Additionally, benefits that would affect the general population as the result of indirect control of other organic emissions in the process of controlling benzene emissions from maleic anhydride plants are not quantified. Possible benzene exposures from other sources also are not included in the estimate. For example, an individual living near a maleic anhydride plant is also exposed to benzene emissions from automobiles. Finally, these estimates do not include possible cumulative or synergistic effects of concurrent exposure to benzene and other substances.

B.7 REFERENCES

1. U.S. Environmental Protection Agency. Industrial Source Complex (ISC) Dispersion Model User's Guide, Volume I. Research Triangle Park, North Carolina. EPA-450/4-79-031. 1979
2. U.S. Environmental Protection Agency. An Evaluation Study for the Industrial Source Complex (ISC) Dispersion Model. Research Triangle Park, North Carolina. EPA-450/4-81-002. 1981.
3. Systems Applications, Inc. Human Exposure to Atmospheric Concentrations of Selected Chemicals. (Prepared for the U.S. Environmental Protection Agency, Research Triangle Park, North Carolina). Volume I (NTIS No. PB81 193252) and Volume II (NTIS No. PB81 193260). May 1980.

4. Albert , R. E. Carcinogen Assessment Group's Final Report on Population Risk to Ambient Benzene Exposures. U.S. Environmental Protection Agency. Publication No. EPA-450/5-80-004. January 1979.
5. Letter from Basil, J. A., Reichhold Chemicals, Inc., to J. L. Warren, Research Triangle Institute, May 2, 1979, (Part II Docket Item II-D-48).
6. Letter from Meyer, A. J., DENKA Chemical Corporation, to J. L. Warren, Research Triangle Institute, May 30, 1979, (Part II Docket Item II-D-51).